National Aeronautics and Space Administration

Our Magnetic Sun
Outreach ToolKit Manual

ToolKit developed by the Astronomical Society of the Pacific in conjunction with
The Center for Science Education at the UC Berkeley Space Science Laboratories

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NASA Night Sky Network

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The nonprofit Astronomical Society of the Pacific (ASP), one of the nation's leading organizations devoted to astronomy and space science education, manages the Night Sky Network in cooperation with NASA and JPL. Learn more about the ASP at: http://www.astrosociety.org.

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Introduction

Welcome to the Outreach ToolKit, Our Magnetic Sun. This ToolKit provides activities and demonstrations that explore the Sun and its powerful magnetic fields, how these fields generate the features we observe, and how the Sun's magnetic activity affects our way of life and technologies here on Earth.

In this ToolKit, we cover these main themes:

- How the Sun's dynamic magnetic activity causes features we see on the Sun
- How that magnetic activity also causes solar storms, which can affect our technologies here on Earth, like GPS and your cellphone
- And that most of the energy consumed on Earth ultimately has its origins in the Sun

Powerful magnetic fields in the Sun generate activity that is the origin of features we observe on the Sun:

- Sunspots
- Plage (pronounced like "garage" and spelled the same whether singular or plural)
- Prominences
- Filaments
- Flares (though these are rarely viewed and must be extremely bright to be visible)

Magnetic activity is also the origin of features our eyes cannot detect, but that spacecraft like the Solar Dynamics Observatory with ultraviolet detectors can detect:

- Coronal Loops
- Coronal Mass Ejections (also called CMEs or "Solar Storms")

Daytime events are a great place to bring out your solar telescope and "wow" the public with views of the Sun. These features inspire awe for us, but if your audience is unfamiliar with the Sun, they might not feel the same "wow" unless you provide some context. For example, in this ToolKit, we use the term "Solar Storms" to refer to CMEs, since we are often addressing a general audience with little background knowledge of the Sun. Bring the science of the Sun down to Earth with these simple demonstrations and activities as you share views of our closest star with your visitors.

Viewing the Sun Safely

NEVER look directly at the Sun without the proper solar filters (NOT sunglasses)! If properly protected, there ARE ways to look at the Sun. We can project it onto paper or even look at it through a telescope with solar filters.

Review this thorough explanation and watch a short video from the Space Sciences Lab:
http://cse.ssl.berkeley.edu/cms/LearningResources/ViewingtheSunSafely/tabid/269/Default.aspx

Background Information

Solar Storms? Why Should I Care?

A Historical Perspective by Dr. Sten Odenwald

"Telephone and telegraph networks failed and equipment burst into flame…a plane crashes killing 18 people…a bustling city loses power trapping thousands of people inside elevators…satellites malfunction and in an instant millions of people lose touch with critical services, doctors and children."

These are not the theatrical elements of some low-grade science fiction movie, they are just a few of the many similar events that played out during severe solar storms of the past century.
Solar storms have always caused spectacular auroras to take the skies, dazzling and humbling all who were fortunate to be in the right geographic locales at the right times. Today, these storms pass by with far more consequence – costly lessons that our technology is still not immune from an ages-old phenomenon.

Long Before Cell Phones

The Sun's constancy as a source of light and heat has been celebrated for millennia, and even deified by many civilizations. Yet this constancy hides a more fickle personality, whose cyclical tantrums of quiescence and storminess has only been recognized 'yesterday' in terms of the great pageant of human history. Before the sunspot cycle was discovered in the mid-1800s, sunspots were a surprising feature of the Sun, but there was little practical benefit to this knowledge. Did their comings and goings have something to do with the weather? The connection between the lovely northern lights and the everyday world was also rather tenuous. Were they really messages from 'beyond' alerting us to some hopeful, or foreboding, event about to happen?

Auroras had held their secrets very tightly for all these centuries. Careful observers soon paid attention to them as astronomical events rather than just some random atmospheric will-o-the-wisp. It didn't take long to recognize that auroras were more common in the northern skies when sunspots dotted the solar surface. Compasses would go haywire whenever a strong aurora peeked its glowing face over the horizon. Still, even with these tantalizing clues, the exact relationship between these dramatically-timed solar and terrestrial phenomena was largely a matter of high-brow conjecture.

At the end of the day, why should anyone on the street care about the appearance of auroras other than their being, for some, an uncommon natural light show to break up the evening rituals after a long day at work?

The Sun-Earth Connection Discovered

This apathetic state of affairs ended on September 2, 1859. In England, the wealthy amateur astronomer Richard Carrington observed a rare but spectacular flare near a large sunspot. Within 17 hours, a domino-fall of invisible events was set into motion, spawning major aurora sightings all around the world. Telegraph disruptions also sprang up everywhere as powerful electrical currents beneath the ground found their way into the high-tech circuitry, bursting some into flame. Among the many newspaper accounts, we hear of Fredrick Royce at a Washington, D.C telegraph office who was nearly electrocuted by these currents while sending a routine message on behalf of a rather impatient client. Over 200 reports filled the pages of the scientific journals and newspapers of the day, reinforcing the perception among scientists and the general public that solar activity could occasionally spawn some very nasty consequences.

Although it was the biggest solar storm in the last 150 years, its technological impact was actually pretty minor. In the tabulation of solar storm disturbances and how they can affect us, timing is everything. In 1859, human society was rather far removed from the kinds of technologies and day-to-day behaviors that connect directly to the Sun's tantrums.

The world-wide telegraph disruptions of 1859 were eventually followed by lesser storms that spawned in their wake, causing progressively more disturbing telegraph disruptions in 1872 and 1882. By the 1890s, the ascendancy of telephone networks and operator-assisted exchanges only transferred these solar storm impacts to another medium. Ground currents created by solar storms found their way into both telegraphic and telephonic systems with nearly equal ease. The advent of Marconi's 'ether' radio introduced us to a new medium for communication, but this only began a whole new round of solar storm impacts, made obvious by the radio disruptions of 1903, 1907 and 1909 during the infancy of the Radio Age. And of course, the impacts on older technologies did not come to an end with the deployment of the newer ones. In fact, by the 1930s solar storms were rattling the cages of all three communications technologies, telegraph, telephone and radio, at the same time! Literally millions of messages, carrying the commerce and private letters of half a world, were held hostage to the fickle ravages of the mysterious solar storms.

This Means War!

As radio technology evolved to utilize shorter wavelengths in the 1930s, hours-long radio blackouts continued to dog even the most advanced radio technology: a technology that was helpless to overcome these persistent solar effects. There seemed to be no escaping these earthly problems, which frequently made front-page headlines in the major newspapers. This spurred on military and civilian efforts to understand the solar-terrestrial connection so that we could at least attempt to predict when these communication outages might happen. The scientists paid attention to 50 years of historical anecdotes and searched the Sun for angry-looking sunspots. They eventually kept round-the-clock watch on the Sun during June 6, 1944, alerting the Allies to flares that could disrupt vital short-wave messages for the most complex military engagement in history: D-Day.

At this point, solar storms were the big news of the day whenever they happened, though no one could predict exactly when. At the height of the interest in solar storms in 1941, the *Boston Globe* sported a front page banner headline 'U.S Hit by Magnetic Storm' in 2-inch letters, previously reserved for announcing major battles during World War II.

We read in yellowed copies of *The New York Times* about the massive rescue mission in 1957 undertaken in the North Sea for the British submarine Acheron. It was presumed lost after failing to radio-in at the planned time - a message intercepted by a raging solar storm instead. After a hundred reports since 1859 of communications problems, fires and social panic, it was inevitable that a solar storm would be credited with taking a human life. This opportunity happened in 1946.

On September 18, 1946 the Belgian Sabena Airways four engine DC-4 aircraft with forty-four persons on board crossed the Atlantic and was scheduled to land at Gander Airport in northeast Newfoundland. About 22 miles southwest of the airport it crashed, taking the lives of 27 passengers.

Why did the crash happen? For centuries, it was well known that aurora could accompany magnetic changes in compasses by up to tens of degrees. Not a serious problem for the leisurely pace of maritime navigation, but at the speed of a modern aircraft, unexpected bearing changes are hazardous, especially when descending through a thick fog. No one can say exactly what the pilot might have been thinking while solar activity played havoc with the flight compass. Descending through the fog bank on what should have been the last minutes on a safe bearing, the plane found itself at treetop level and collided with a thick stand of pines. At 200 mph, death came in less than a second. The Minister of Budget in Brussels announced soon afterwards that the main cause of the crash was fog and the aurora borealis, whose fading beauty could be seen in the skies over the crash site.

Into the Space Age and 21st Century Communications

As we entered the Space Age and the turn of the 21st Century, the impact of solar storms on our way of life gradually increased until . . .

On March 13, 1989 a massive solar storm caused an electrical power blackout in Quebec that eliminated light and heat for 3 million people, created a major political firestorm, interrupted critical medical operations, and led to charges of incompetence in the Quebec power industry. The same event may have triggered irregular sensor readings during the launch of the Space Shuttle. The Quebec Blackout was THE major and to scientists almost legendary textbook example of how solar storms can cause obvious problems.

As of this writing, many space physicists have expressed amazement in our good fortune that no electrical blackouts have since occurred on the scale of the Quebec March 13, 1989 event. There was a minor electrical blackout in Sweden during the Halloween 2003 storm, but it lasted only a few hours and affected only 50,000 people. Yet even without a major blackout since 1989, there has been plenty of damage to other segments of our technology not as lucky as our electrical power grid.

Satellite outages reported during the sunspot cycle of 1996-2007 rendered 18 satellites disabled, at a cost of nearly $3 billion. Many research satellites have been frequently rendered temporarily unusable by powerful solar flares and particle storms. During the Halloween 2003 storm, no fewer than 46 severe satellite problems were documented. Most of these were followed by a full recovery, but several resulted in permanent satellite damage.

International Space Station astronauts had to take cover during the November 4, 2003 storm events, yet still reported high radiation doses that were about twice the normal levels. Long duration human voyages to Mars would no doubt encounter quite a few flares. We know what to expect from them because we have been this way many times before with unmanned spacecraft.

Even now, Mars-orbiting satellites have reported that this environment is about twice as ‘hot’ as the one near the International Space Station. Upon arrival at Mars, astronauts would have to be shielded round-the-clock to reduce their cumulative radiation dosages to the recommended safe levels. But you don't have to be an astronaut to worry about solar storm radiation. During the Halloween Storm, the Federal Aviation Association instructed passenger jets flying Arctic polar routes to do so at lower than normal altitudes to make the trip safer for passengers and crews.

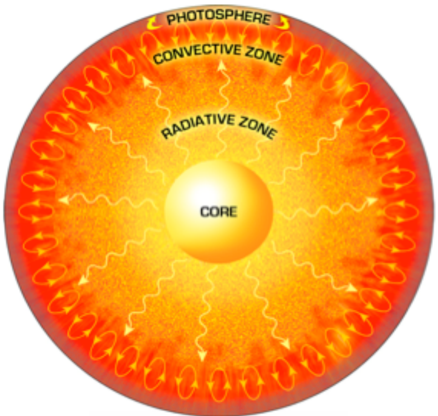
Keeping Close Watch on the Sun

The story of human lives crossed by solar storms, and what lies in store for us in the future, began in the closing days of summer in the year 1859. Like so many other natural phenomena, solar storms and the beautiful aurora that often accompany them, have been known to us for a long time. And as with many of the other natural disasters, they first began as annoyances, only to become severe problems as population pressure and advancing technology relentlessly placed us into closer conjunction with them.

Today we care deeply about the effects that space weather can have on our way of life. Space agencies have placed numerous instruments on a variety of satellites that are keeping a close eye on the Sun, watching its every flicker. These missions help us determine how the inside of the Sun works, how energy is stored and released in the Sun's atmosphere, and how to track the flow of energy and particles from the Sun to the Earth.

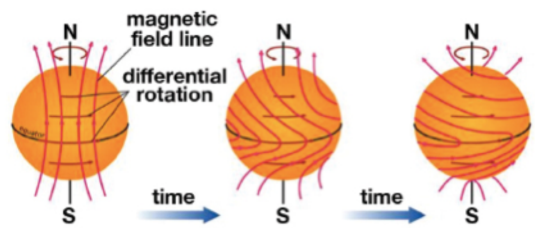
By better understanding the Sun and how it works, we can better predict solar storms and provide earlier warnings to help protect ourselves and our technologies from that weather out in space.

How Flares and Coronal Mass Ejections (CMEs) Wreak Havoc



Solar Interior

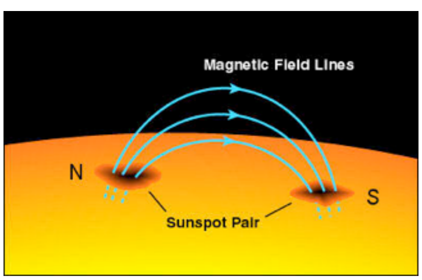
It all starts with sunspots. Sunspots are the visible footprints in the **photosphere** of relatively strong magnetic fields that emerge from below the **photosphere**. The Sun's magnetic fields are generated in its **convective zone**. See the illustration "*Solar Interior*."



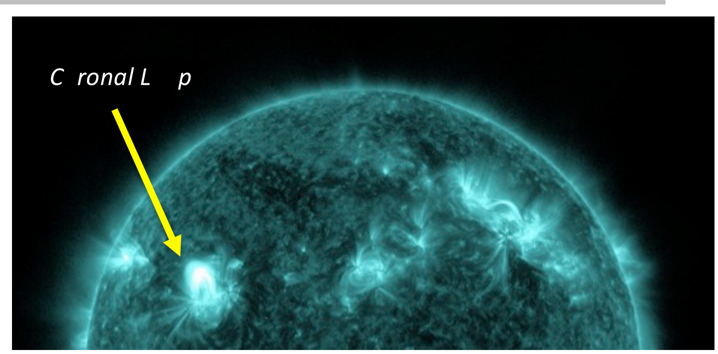
Magnetic fields lines warp and twist over time.

Since the Sun spins faster at its equator than at its poles, its magnetic field lines become warped and twisted, sometimes causing part of a magnetic field line to pop through the photosphere. It takes roughly 11 years for the Sun to move through the **solar cycle** that is defined by an increasing and then decreasing number of sunspots.

Sunspots usually come in pairs, one with a north polarity and one with a south polarity. Magnetic field lines are defined as having north and south polarity, even though geographic north (or south) might not be the actual direction they follow. For example, a bar magnet has magnetic field lines running from one end of the magnet to the other; one end is designated as "north," and the other end is designated as "south." You can hold a bar magnet in any orientation, and it always has a north end and a south end. This ToolKit uses compasses to illustrate magnetic fields and what directions they flow.



Solar Flares and Solar Storms



Material from the Sun's corona (or atmosphere) gathers around the magnetic field lines over the sunspots, glowing hot and bright in ultraviolet radiation, forming coronal loops.

The corona is a plasma – material that is so hot that the negatively charged electrons are ripped from the positively charged nuclei of the atoms, resulting in material that is electrically charged (filled with positively and negatively charged particles).

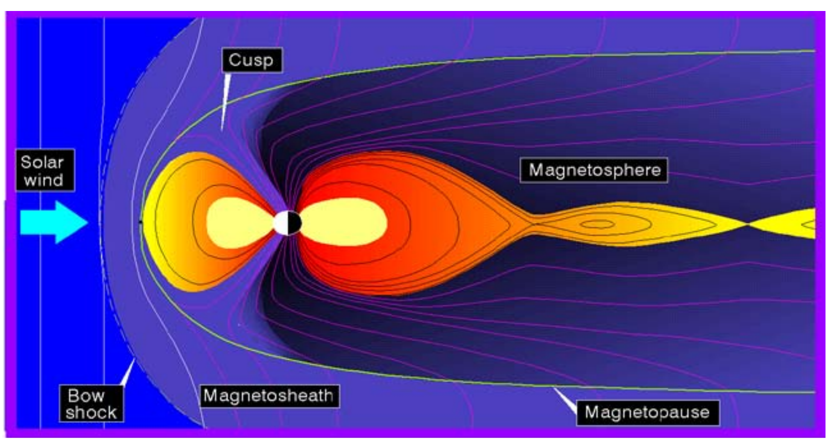
If the coronal loops change and twist, the coronal material can behave somewhat like a short circuit, causing an explosive flare-up called a "**solar flare.**" A flare can release X-rays that reach Earth in just over 8 minutes (because X-rays are a form of light energy and therefore also travel at the speed of light). If the explosion is large enough, a cloud of charged particles can escape the Sun and travel out into the Solar System. If that happens, the cloud of charged particles is called a "**Coronal Mass Ejection**" or **CME**. In this ToolKit, to reduce the use of jargon in public presentations, CMEs are referred to as "**solar storms**."

When a powerful **solar flare** occurs, the X-ray energy from the flare, if directed toward Earth, can strike the dayside of Earth's atmosphere, heating it and causing the atmosphere to expand. This can cause atmospheric drag for satellites in low-Earth orbit. X-ray energy can also suddenly interrupt signals from satellites, such as GPS. The radio communications disruptions caused by a solar flare are often due to the reaction of the ionosphere to the X-rays. Signals from satellites are degraded and scattered as the signal passes through the ionosphere that has been deepened by all the X-rays. This radiation can also pose a danger to space-walking astronauts.

When a **solar storm** (CME – a cloud of charged particles) occurs, it can sometimes be directed toward Earth. Depending on how fast the storm is traveling, it can take one to three days for that cloud of particles to cross the 93 million miles to Earth.

The first thing to remember about the effects of a solar storm (CME) striking Earth is that the particles (electrons and protons) in the solar storms do not directly enter the Earth environment because the Earth's magnetic field deflects them. It's the interaction of the solar storm with Earth's magnetic field that wreaks havoc.

Earth's **magnetosphere** (the region around Earth influenced by Earth's magnetic field) creates radiation belts of high-energy particles, and a solar storm can make these radiation belts (the Van Allen belts) extra dangerous. The solar storm can impart energy to the magnetosphere, which can cause electrons and protons in the magnetosphere to be accelerated to very high speeds. These fast-moving particles can impact satellites, potentially causing damage.



Detectors (particle and CCD) on satellites can also be degraded in sensitivity by exposure to the high-energy particles over time.

Earth's magnetic field can be disturbed and shifted by the impact of the solar storm. Shifting, moving magnetic fields induce electrical currents (illustrated in the activity, *The Magnetic Connection*, in this ToolKit). Those magnetic disturbances induce electrical currents in Earth's atmosphere, high in the ionosphere. It is called the ionosphere because it is filled with free electrons and ions – atoms and molecules that have charge because many of the atoms have lost one or more electrons. The ionosphere is electrically charged and has much higher density than the solar storm (CME) cloud.

The solar storm then can enhance the aurora and affect the power grid. This is basically a chain of magnetic-electric inductions:

1) The Earth's magnetic field absorbs energy from solar storm (CME) impact, which induces electric currents in the charged particles of Earth's magnetic field.
2) Those currents are directed along magnetic field lines toward Earth's polar regions and into the atmosphere and create the aurora.
3) Since the current is dynamic, the magnetic field it produces is also dynamic, which, once again, induces electric fields on the surface of Earth that will drive currents in anything that will conduct them, like oil pipelines and electrical grids.

If the current induced in the electrical grid is too high, it can blow out transformers and take down either the entire grid or just parts of it. This has plunged cities into darkness, as it happened in Canada in 1989.

Solar flares and solar storms (CMEs) can affect life on Earth in different ways. Both solar flare X-rays and the CME particles can directly and indirectly affect satellites, including interrupting their signals and changing their orbits.

Why Does the Sun Have Magnetic Fields?

This is still an active area of research. For a thorough discussion, refer to this article on the Sun-Earth Day website:
http://sunearthday.nasa.gov/2008/TTT/60_magfield.php

Why Does the Earth Have a Magnetic Field?

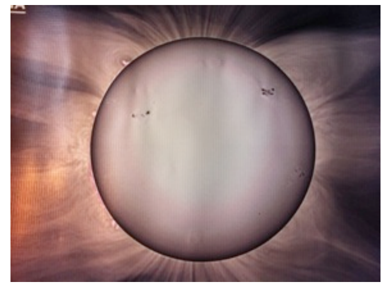
Adapted from NASA's Goddard Space Flight Center:
http://image.gsfc.nasa.gov/poetry/magnetism/magnetism.html

Although the Earth's crust is solid, the core of the Earth is surrounded by a mixture of molten iron and nickel. The magnetic field of Earth is caused by currents of electricity that flow in the molten core. These currents are hundreds of miles wide and flow at thousands of miles per hour as the Earth rotates. The powerful magnetic field passes out through the core of the Earth, passes through the crust, and enters space.

If the Earth rotated faster, it would have a stronger magnetic field. If it had a larger liquid core, Earth would also have a stronger magnetic field. By the time the field has reached the surface of Earth, it has weakened a lot, but it is still strong enough to keep your compass needles pointed towards one of its poles.

A compass works the way it does because Earth has a magnetic field that looks a lot like the one in a magnet. The Earth's field is completely invisible, but a compass needle on the Earth's surface can feel it, and it reaches thousands of miles out into space. If you were to study the Earth's invisible magnetic field from space, it wouldn't really look like the magnetic field around a bar magnet at all. Earth's magnetic field gets stretched out into a comet-like shape with a tail of magnetism that stretches millions of miles behind Earth, opposite from the Sun.

What Color Is the Sun Really?



The Sun is really white. This ToolKit shows images of the Sun in a variety of colors. Color is used to enhance features and distinguish wavelengths.
The Sun's true color though is white, as depicted in the lower image on the banner, which is a composite of the white light image (Photosphere) superimposed over an image of the corona from a solar eclipse.

Discussion of Models and Their Usefulness

These materials include models to demonstrate a variety of concepts. Models are useful, but their utility is always limited in some ways. It is often helpful to discuss the strengths and limitations of models with your visitors. For example, the nine-inch half-sphere in the ToolKit represents the Sun.   What are some of its strengths as a model? How is it useful?   Where does this NOT represent reality? What can't it be used for? These are questions you might want to include in your discussions with your visitors as they explore the Sun with these materials.

What Are QR Codes?

(adapted from an article on http://socialmediadiyworkshop.com)

The Banner as well as some of the "Explore the Sun" cards have QR Codes on them, like the one here on the right. If you are unfamiliar with these, here is a little bit of background information. This one on the right links to current views of the Sun from the Solar Dynamics Observatory:
http://sdo.gsfc.nasa.gov/data/

QR (for Quick Response) codes are a shorthand way to represent information, commonly used to store special website addresses. Smartphones can read these codes with specialized software (apps) installed on the phone. Using the app, you scan the code with your cell phone camera, and the QR code software uses the phone's network to take you to the Internet address hidden in the code. This process is also known as mobile tagging.

Additional astronomy activities can be found here: http://nightsky.jpl.nasa.gov

Where Could I Use These Activities?

MEDIA / RESOURCE	Solar Viewing	Indoor Public Event	Girl Scouts / Youth Group Meeting	Classroom			Club Meeting	Gen Public Presentation (Seated)
				K-4	5-8	9-12		
Training DVD							√	
Manual & Resources CD							√	
Sun in a Different Light Banner and Model	√	√	√		√	√	√	√
Explore the Sun Cards	√	√	√		√	√	√	
Magnetic Connection Box	√	√	√		√	√	√	
Protection from Ultraviolet	√		√	√	√	√		
Where Does the Energy Come From? Cards	√	√	√	√	√	√	√	
PowerPoint: Space Weather		√	√		√	√	√	√

The Sun in a Different Light - *Banner and Model*

What's this Activity About?

Objectives:

1) Prepare the visitors for the experience of observing the Sun
2) See how different wavelengths of light reveal the variety of features caused by the Sun's magnetic activity
3) Introduce solar storms
4) Allow visitors to envision the Sun as a sphere
5) Explore how the Sun's internal structure contributes to generating the Sun's magnetic fields

Presenters: A minimum of one person.

Duration: A few minutes, up to a half hour, depending on the number of topics covered.

Visitors: Appropriate for families with older children, the general public, and school groups in fifth grade and up. Any number of visitors can participate.

Materials:

What materials from the ToolKit do I need?

1) Banner with 4 Sun images on the front and magnets on the back
2) Bag with a few pipe cleaners: red "prominences" and silver "coronal loops"
3) 3D Sun Model attached to banner (optional)
4) One small compass (optional)
5) Explore the Sun card: "How is the Sun like a Boiling Pot of Spaghetti?" (optional)

What must I supply?

Scissors to cut pipe cleaners

What do I need to prepare?

The first time you use this activity, simply cut the shiny pipe cleaners into short strips. Red strips should be about 1 inch/2cm and model prominences and filaments. Silver strips should be about 2 inches/5cm and bent into U shapes. Also, place the compass on the banner by sticking one of the Velcro dots to the back and the other to a corner of the banner. You can store the compass and pipe cleaner bits in the included bag. The bag can be attached to one of the grommets on the banner. If using the 3D Sun model, attach that to the banner with the text upright, as shown to the right.

Where do I get additional materials?

1) Banner: The PDF for this banner is on the Manual & Resources CD. The file name is "MagSunBanner.pdf". You can have a full-size banner made at a printing company.
2) Metallic silver and red pipe cleaners (also called "tinsel stems") are available at craft stores.
3) A small compass and magnets for the back of the banner can be found online.
4) The half-sphere 3D Sun was custom made and is not commercially available.

Activity Script

Leader's Role *Participants' Role*
(Anticipated)

To do:

Have banner hung or placed on a large table for visitors to view.

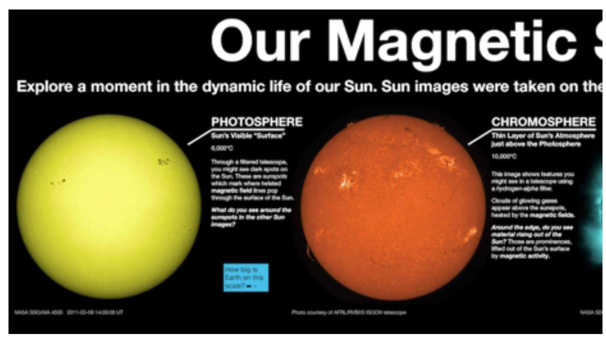
To say:

These three images of the Sun were taken on the same day (March 6, 2011) using different kinds of detectors. They allow us to examine more than we can see simply with our eyes.

Who can tell me what they see on these images of the Sun?
How are they the same? What's different?

Various answers

These features are all caused by the dynamic magnetic activity of the Sun. If the Sun did not have changing magnetic activity, it would have a plain, uninteresting face.



To put the size of the Sun in perspective, this little dot in the blue box shows how big the Earth is compared to the Sun at this size – about as big as some of these sunspots that we see in this yellow image on the left. This image is what we would have seen that day in a filtered white light scope.

This middle image is what we would have seen that day in a hydrogen alpha telescope. What do you notice that you don't see in the first image?

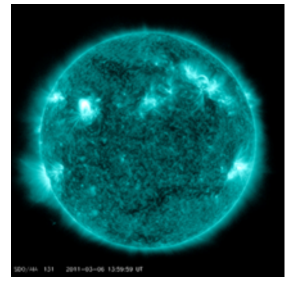
White areas, dark streaks, red arcs around the edges

Right – the bright areas are called plage (*pronounced like garage*), like clouds above the sunspots. See how white they are – that means they are hot – generated from material heated by the strong magnetic fields around the sunspots.

Who can find a finger of material rising from the side of the Sun? Those are prominences, material lifted out of the Sun's surface by magnetic activity. How about some darker filaments snaking across the Sun's face? Filaments are just prominences as seen from above, silhouetted against the brighter Sun. They're really the same thing.

To say:

NASA's Solar Dynamics Observatory – a space-based mission, took this third image. If you had eyes like that spacecraft, you could see features like these that are at much higher temperatures, over a million degrees.



What is around the sunspots here?

Bright loops!

These are called coronal loops. Coronal loops form from material in the Sun's corona, or atmosphere. That material is caught in the magnetic fields around sunspots – following the magnetic field lines – like the ones you see in the image on the right.

To say:

This lower image shows the outer atmosphere of the Sun – the Corona – all these particles are streaming away from the Sun all the time.

Sometimes the Sun releases a storm of material. We can see that happen in this video.
This video shows three days (March 5-7, 2011) on the Sun, days that span when these images were taken.

To do:

Show video at:
http://www.astrosociety.org/samplers/DynamicSun4Views.mov
Or scan the QR Code on the bottom left of the banner with a smartphone.
(See Background Information for an explanation of QR codes.)

To say:

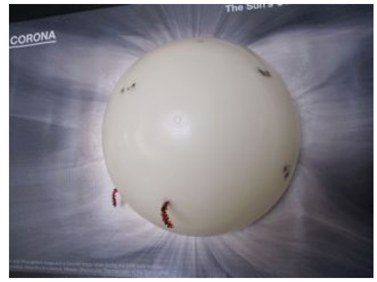
Enjoy your views of the Sun through the telescope – see how many of these features you can find.

Activity Script Extensions

If using the 3D Sun model, you can make the following points as well.

To say:

We can give our model of the Sun some prominences and filaments.

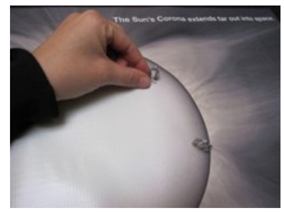


To do:

Rotate the model to show how the filament can become a prominence.

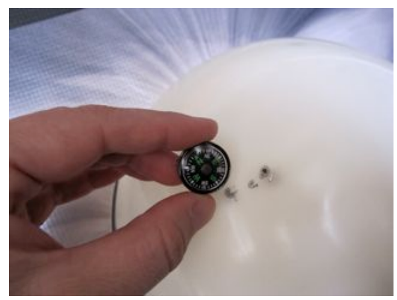
To do:

Use the silver pipe cleaners to form a loop over the sunspots on the 3D model or on the banner. Let visitors do the same.



To say:

On our Sun model we can use a compass to follow the magnetic field lines around the sunspots.



To do:

Trace the magnetic field lines of the sunspots.

To say:

These features are all generated because the Sun has a lot of magnetic activity, creating magnetic fields that pop through the visible surface of the Sun. But where are the magnetic fields generated? Let's look INSIDE the Sun.

To do:

Hold up the 3D Sun model and show interior. Bring out the "How is the Sun Like a Boiling Pot of Spaghetti?" card and indicate the regions as you talk.

To say:

What do you see in there?

The core. Various answers.

The core of the Sun is very hot – millions of degrees! The pressure is so great that the material is quite dense. The core is so dense that a quart of material from the core would weigh more than a person (indicate yourself or another adult in the group). That density and pressure is what causes the Sun to generate energy, by fusing hydrogen into helium.

Who has ever boiled spaghetti on a stove? Let's think of the inside of the Sun like a thick-bottomed pot of water and spaghetti boiling on a stove.

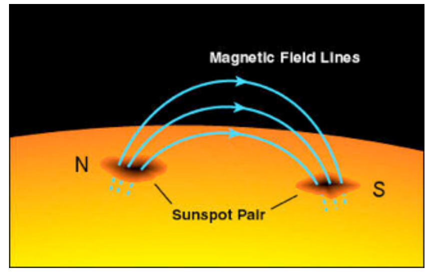
You can think of the core as the burner on the stove.
The core blends into the radiative zone where energy continues to be transferred out through radiation. It's still pretty dense, like a thick bottom of that pot.

Here in the convective zone the density is low enough to allow the material to move, like water in that thick pot. Deep in this boiling convective zone is where the magnetic field lines are generated and then get twisted up (kind of like strands of spaghetti in the boiling pot of water). Sometimes the magnetic field lines pop through the surface – to make a sunspot. Sunspots are the footprints where the magnetic loop emerges from the surface.

Background Information

During a given sunspot cycle, the leading sunspots in groups in the northern hemisphere of the Sun all tend to have the same polarity, while the same is true of sunspots in the southern hemisphere, except that the common polarity is reversed from that of sunspots in the northern hemisphere. So the magnets in the 3D model have north leading in the northern hemisphere and south leading in the southern (or vice versa).

Sunspots have polarity because they are just the visible manifestation of a magnetic field line emerging above the visible surface of the Sun. A magnetic field line has north-south polarity, even when it is twisted or bent.



Presentation Tips:

- Use the Explore the Sun cards to help answer visitors' questions.
- Show visitors real-time views of the Sun in different wavelengths:
  - Have your visitors compare what they see in the telescope right now to images acquired from other telescopes.
  - If you have Internet access, use a computer or smartphone to see the most current images of the Sun from the Solar Dynamics Observatory (SDO) (taken within the last hour) and from the National Solar Observatory (NSO).
    - For seeing the current view of the Sun in H-alpha, go to the National Solar Observatory website: http://halpha.nso.edu/
      NOTE: All times are in Universal Time.
    - For viewing other wavelengths on a computer go to the SDO website: http://sdo.gsfc.nasa.gov/
    - For other wavelengths on a smartphone, download the app:
      - iPhone: 3D Sun and Space WX
      - Android: SDO app from ASTRA
    - Then, to see the latest images:
      - Select the "AIA 4500" for a visible light image. It should look very much like what you see in the telescope.
      - Select the "AIA 131" image for the extreme ultraviolet image.
      - Select the "AIA 304" image to see prominences that might also be visible in H-alpha scopes.

Explore the Sun Cards

What's this activity about?

Objective:

- Provide visitors with ways to understand more about the Sun and its magnetic fields
- Provide presenters with illustrations to help answer visitors' questions about the Sun

Presenters: Cards can be used with or without a club facilitator.

Visitors: Cards are appropriate for families with older children, the general public, and school groups in fifth grade and up. Any number of visitors can participate.

Duration: A few minutes, up to a half hour, depending on the number of topics covered.

Materials:

What materials from the ToolKit do I need?

Set of 11 *Explore the Sun* cards with accompanying props: Sombrero, UV beads, Sunspot Tube, and Solar Viewer. No preparation is necessary.

Where do I get additional materials?

1. Print cards from the file on the Manual & Resources CD. You can find the file ExploreSunCards.pdf in the folder titled Masters. This includes a page of printing instructions.
2. UV beads can be found many places including Educational Innovations: www.teachersource.com
3. Sombreros or small hats can be found at craft stores. Alternately, old baseball caps can work.
4. Solar Viewers can be ordered online. Search for Solar Viewers or eclipse glasses.
5. Cardboard mailing tubes can be found at shipping centers.
6. Glow-in-the-dark stickers can be found online.

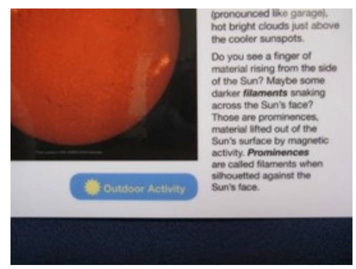
Activity Ideas

The *Explore the Sun* cards can be used in many ways. Use them all or choose a subset that pertains to your topic or theme that day. They are designed to be self-explanatory, so visitors can explore them on their own in a variety of settings. Alternately, they can be used in groups or individually as facilitated explanations. Each card has an eyelet so you can tie them to the leg of an observing table or tie them to a fence or just tie them together to keep them as a set.

Here are some suggested ways to use the cards:

- Hang in a line on a rope tied to a fence or other display area.
- Hand out to visitors waiting in line at the telescope.
- Use as props to illustrate answers to questions raised by visitors.
- Pick a few to present to visitors at a display table or at the scope.

These cards use analogies to explain visible phenomena, or set expectations of what visitors might see at the telescope. They explain filters and the solar cycle and expand on the concepts of magnetism. Some of the cards need to be used outdoors. You'll see this small Sun symbol on the back of those, indicating that it's an Outdoor Activity.



Some cards have QR codes, squares with a pattern of dots. They are codes that can be decoded using a smartphone. If you're not familiar with these, check the **Background Information** for an introduction.

Magnetic Connection

What's this Activity About?

Objective:

1) Introduce the connection between the Sun's magnetic activity and Earth's magnetic field
2) How solar storms are generated from the Sun's magnetic activity
3) How solar storms interact with Earth's magnetic field to affect Earth's infrastructure

Presenters: A minimum of one person.

Visitors: Appropriate for families with older children, the general public, and school groups in fifth grade and up. Up to about 5 visitors at a time can participate comfortably.

Duration: From 10 minutes up to a half hour, depending on the number of topics covered.

Materials:

What materials from the ToolKit do I need?

- Box with Velcro dots
- 1.5 - 2" (4 – 5 cm) rod magnet
- 4 compasses
- A shake flashlight
- Two cards, one with images of Earth's and Sun's magnetic fields, and one with aurora and a Presenter's Guide
- "Solar Storm" plastic arc

What do I need to prepare?

Materials Assembly when Using for the First Time:

Apply the Velcro dots in the pattern shown in the picture below. Notice that there is a soft loop side and a rougher hook side. Apply the softer loop dots to the top of the box – one in each corner about 2 in/5cm from the sides and one in the middle – just peel and stick. Now put the hook sides of the dots on the back of the four compasses and one on the rod magnet.

Apply the stickers that say "Solar Storm" to the top of the plastic arc to create prop that mimics a wave of charged particles coming from the Sun, also called a Coronal Mass Ejection or CME. (See **Background Information** for an explanation of solar storms.) You'll see that the bottom of the arc has magnets attached to it.

All of these bits -- the arc, the flashlight, the compasses, and pictures -- can all be stored in the box for easy transport.

Getting set up each time:

1) Be sure that everything has been removed from the box and that all metal and magnets are at least a couple of feet away so they don't interfere with the compasses. This includes making sure the table you're using doesn't have metal supports right under your demonstration.
2) Sometimes when a compass is exposed to a strong magnet it becomes demagnetized. Each time you present this demonstration, you'll want to make sure your compasses are all pointing in the same direction – North. If they're not, you can easily realign them by swiping the rod magnet over the surface using the following steps:

- First, select a compass that is working correctly
- Next, determine the north end of the rod magnet by holding it against the side of a *working* compass
  The north end of the magnet will attract the north arrow of the compass that is working correctly
- Now select the non-working compass and place the **north end** of the magnet against the **south mark** on the compass
- And slide it across the top of the compass toward the north compass mark

Where do I get additional materials?

- The images can all be found on the Manual & Resources CD, in the folder Masters, as well as online at:
  - http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=493
- A small pizza box can be used as a replacement if necessary.
- Magnets can be found online. For the strong rod magnets in the center of the box, we used:
  - 3/16'' Dia x 1/2'' Long Rod Grade N40 Neodymium Rare Earth Magnet, item #R500A2 from Amazing Magnets: www.amazingmagnets.com
- Search the Web for "clear shake flashlight". At the time of printing, you can find them here: www.quakekare.com

Optional Introduction to Magnetic Connection:

Have you ever heard of the northern lights? Also called aurora borealis or just the aurora for short. Where on Earth do people see those? Has anyone here ever seen them?

The aurora is a beautiful display of colored lights that dance across the sky. And they are usually seen very far north, in Alaska and Russia for example. But that's not always the case. Let me tell you about a very unusual case of aurora.

It was the evening of September 3, 1859. Before cell phones, or even regular landline telephones were invented. It was before people had TV, and even before radios. It was a dark time in many ways.

Auroras were particularly spectacular and bright that night, brighter than a full moon and filled with vibrant colors. In New York, it was reported that you could read a newspaper by the light of the aurora. Gold miners in Colorado got up in the middle of the night to fix breakfast, thinking dawn had arrived. Not to mention, these beautiful lights could be seen as far south as Florida! That's very far south for the "northern lights". But that wasn't all.

Another very strange thing happened that day. Remember there were no phones yet, but people could still send messages. They used machines called telegraphs that were connected by wires and worked by tapping out Morse code.

That night, telegraph systems all over North America and Europe stopped working. Operators couldn't send signals because the wires had gone crazy. Some even received electric shocks and the paper they were printing spontaneously caught fire. Even when the wires were disconnected, some systems continued sending signals. It was definitely not business as usual.

But there is one more piece to the puzzle. It so happened that just the day before, British astronomer Richard Carrington became the first person to see a huge bright flash on the Sun. He wasn't sure what it was he was seeing. This was the first time anyone had witnessed a solar flare!

And then the lights in peoples' heads started to go off. Maybe that huge solar flare had something to do with the beautiful lights and the strange telegraph disruption. When scientists started putting all of these pieces together, the study of solar storms began. **This was the first time that we realized that changes in the Sun could have dramatic consequences for us here on Earth.**

Let's take a look at what was happening that day when the telegraph went haywire. *(Introduce the Magnetic Connection demonstration)*

Activity Script

Leader's Role *Participants' Role (Anticipated)*

To say:
We're talking about the Sun today, and I have some compasses here. But what do compasses have to do with the Sun? Well, let's start by asking where do compasses point?

North pole

OK. Earth has fairly regular magnetic field lines that run north and south. The compasses follow those magnetic field lines.

To do:
Refer to image of Earth's magnetic field.

To say:
If we place a magnet into the middle of these compasses, will they change the direction they're pointing?

Maybe, yes, don't know.

To do:
Hand the bar magnet to a visitor.

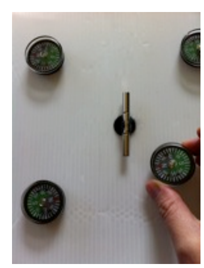
To say:
Let's find out. Would you slowly lower this magnet onto the board?
Whoa. What happened?

The compasses all changed direction.

Sure – the compasses are now following the North to South magnetic field lines around this magnet. Who would like to follow the magnetic lines down the other side?

I do!

To do:
Detach one of the compasses and follow the N->S lines on one side of the magnet.

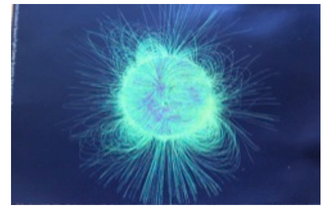


To say:
OK, let's take this magnet out. Where will the compasses point after we take it out?

Back to Earth's magnetic field.

Well, we saw that Earth's magnetic field is fairly regular. But the Sun has more complicated magnetic fields.

To do:
Show Sun's magnetic field image.

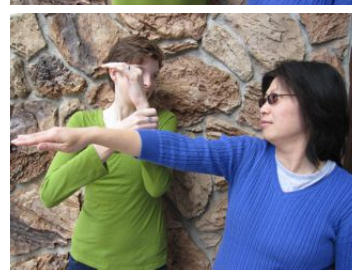


To say:
Would you be able to navigate on the Sun using a compass?

No!

From a distance, the Sun has roughly the same pole-to-pole field, but below the surface, the magnetic field lines are tangled and irregular. Sometimes, field lines will loop and pop through the surface of the Sun.

To do:
Use your hands and a visitor's arm to illustrate how a loop comes up through the surface, as shown in the pictures on the right. A video of this demonstration can also be found here:
http://www.astrosociety.org/samplers/Solar_Storm_Demo.mov



To say:
Put your arm straight out. Your arm will represent the surface of the Sun.

My arms represent a magnetic field line that gets twisted and pops through the surface.

Has anyone seen sunspots in the telescopes today? Sunspots occur here, where this loop emerges. They're the footprints of the magnetic field lines on the visible surface of the Sun!

These magnetic loops gather material from the Sun's atmosphere, and it spirals around the loops.

Sometimes the loops can reconnect, and like a short circuit, can generate a sudden release of energy. This can violently blow part of the atmosphere away from the Sun and eject it into space. We call that a solar storm.

To do:
Bring out the Solar Storm arc.

To say:
This represents a part of the solar storm.

The corona of the Sun is about a million degrees, so it's too hot for electrons to remain associated with the positively charged nucleus of the atoms in the corona. Thus, the solar storm is an enormous cloud filled with positively and negatively charged particles, represented by these magnets. It usually takes two or three days for this cloud to reach and wash over Earth. As we move the solar storm toward Earth what going to happen to the magnetic field? Let's watch.

To do:
Move solar storm across top of the box at a moderate rate, not too fast, about 1 inch/2cm above the compasses.

Watch the compasses go crazy.

To say:
The particles in the solar storm excite the atoms in Earth's magnetic field, causing it to shift around. Perhaps you know that moving magnetic fields can generate an electrical current.

Please take this flashlight and shake it vigorously for several seconds. The moving magnet in the flashlight generates a current that allows it to light up.
[*Note*: If you are outside in the Sun, you might have to put the flashlight into shadow or point it at a dark surface to see it light up.]

Shake and turn on flashlight.

This happens on a much larger scale on Earth. Those generated currents can enhance the beautiful aurorae by exciting the gases in our atmosphere, just like the gases in a neon sign.

To do:
Show aurora card.

To say:
They can also induce electrical fields at Earth's surface that can blast along our electrical grid, overloading the grid and blowing out transformers. This happened in Canada in 1989, causing a widespread blackout over eastern Canada and into the US. Fortunately, just as we now understand how earthquakes can shake buildings and build them to

withstand the force, power companies have developed new ways to help protect our electrical grid from these electrical surges.

Who has a cell phone? Who has used a GPS device?

Raise hands.

The solar storm can impact and short-circuit orbiting satellites, causing things like long-distance cell phone service to be interrupted. Changes in Earth's magnetic field can confuse navigational sensors on satellites, like those used for GPS. Satellites can be protected by proper shielding and, given enough notice, satellites can be powered down temporarily to protect their electronics. But communications that depended on those satellites would still be interrupted.

NASA and other international space agencies have placed numerous instruments on a variety of satellites that are keeping a close eye on the Sun, watching its every flicker.

Since many spacecraft are tracking activity on the Sun, we can see when a solar storm is ejected from the Sun. We have a couple of days to prepare before it arrives. If I throw a snowball at you (pick someone from the back), you can *see* the snowball in my hand, then you can react by putting your hands up before it reaches you.

By better understanding the Sun and how it works, we can better predict solar storms and provide earlier warnings to help protect our technologies from that weather out in space.

Protection from Ultraviolet

What's this Activity About?

Objectives:

1. Explore ultraviolet (UV) light and how it can be blocked by different materials
2. Explore different kinds of energy: heat, visible light and invisible light from UV rays
3. Understand that Earth's atmosphere protects us from most of the harmful UV rays
4. Understand ways we can protect ourselves from the Sun's harmful rays

Presenters: A minimum of one person.

Visitors: UV beads are appropriate for families with children, the general public, and school groups in third grade and up. Any number of visitors can participate.

Duration: A few minutes, up to a half hour, depending on the number of topics covered.

Materials:

What materials from the ToolKit do I need?

- Handful of UV beads in an opaque bag
- Prepare a few pipe cleaners by placing 4-6 UV Beads on each and wrapping in a ring, as seen here. This helps avoid loss and makes them easier to handle, especially for young children.

What must I supply?

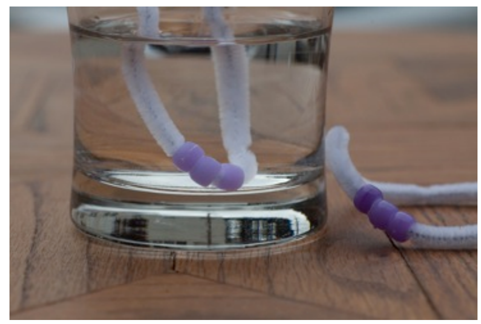
You and your visitors provide various items / materials / conditions for testing UV blocking, for example:

- Sunglasses
- Hat
- Sunscreen in plastic baggie
- Clear plastic cup with water
- Sunny spot and shady spot
- Cloth

Activity Script

To do:
Before participants arrive, place some UV beads in your pocket or in a container that will block any exposure to the Sun. Set up a station that includes a sunny and shady spot, and put out the materials for participants to test UV blocking. If you have sunscreen, squeeze some into plastic baggie and drop in a bead.

To say:
The Sun gives off different kinds of energy, including heat, visible light, and invisible light such as ultraviolet (or UV) energy. UV is high in energy and can therefore be harmful to living things, but luckily the Earth's atmosphere protects us from most of the harmful UV rays. Some of it still gets through, but we can protect ourselves in other ways. In my pocket, I have beads that turn color when they are exposed to UV rays. The beads detect the ultraviolet light coming from the Sun and the darker the bead, the more ultraviolet is getting through the atmosphere to us on Earth.



Engage visitors with questions such as:

- Where do you think the beads will turn the darkest?
- Do sunglasses protect our eyes from UV? How about regular glasses?
- What will happen if we put some beads in this cup of water?
- Are we protected from UV in the shade?
- What other conditions or materials might protect us from UV?

To do:
Get visitors to make predictions and try them out by observing what happens when UV beads are placed in a sunny spot, a shady spot, under sunglasses, under eyeglasses (provided by a participant perhaps), in the cup of water. Then participants can try other materials and conditions, for example, how are their own shirts and hats for blocking UV?

Presentation Tip:

If using this activity in classroom setting, excellent extensions -- including assessment and mapping to national standards – can be found here:
http://solar-center.stanford.edu/activities/uv.html

Where Does the Energy Come From? Cards

What's this Activity About?

Objective: Lead participants to discover that the Sun is the ultimate source of energy for almost everything that we do in our daily lives.

Presenters: A minimum of one person.

Visitors: Most activities are appropriate for families with older children, the general public, and school groups in as young as kindergarten. Between 10 and 30 visitors may participate.

Duration: Between fifteen minutes and a half hour, depending on the number of topics covered.

Materials: Set of energy cards, one card per participant

Note: There are 15 laminated Energy Cards in the ToolKit. An additional 15 cards that you can print are found in the Masters folder on the Manual & Resources CD or online here: http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=494
If you have fewer than 15 (or 30) participants, be sure that the subset you choose consists of complete energy chains, ideally with a variety of types of chains – both technology and life. We recommend that you sort the cards yourself ahead of time to become familiar with which chains might be formed. Each chain has several options, with no single "right answer". Here are some examples of sets of cards for different sized groups:

- 10 participants – Sun, Corn, Ancient Plants, Solar Power Plant, Cow, Burger, Human, Coal, Thermal Power Plant, Light Bulb
- 15 participants – All of the cards for 10 participants, plus: Cereal, Cheese, Petroleum, Automobile, Refrigerator
- 20 participants – All the cards for 15 participants, plus: Oak Tree, Squirrel, Hawk, Computer, Light Bulb (CFL) (Note: more than 15 participants will require that you print the additional cards found in the manual.)
- 25 participants – All the cards for 20 participants, plus: Wind, Windmill, Soy, Tofu, Human (Vegetarian)
- 30 participants – This will require all of the cards. This will include all the cards for 25 participants, plus: Phytoplankton, Krill, Humpback Whale, Apple Tree, Light Bulb (LED lamp)

This activity is based on the Energy Flows curriculum guide from the National Energy Education Development Project (NEED): http://www.need.org/needpdf/Energy%20Flows.pdf

Activity Script

Leader's Role ***Participants' Role (Anticipated)***

To say:
Who's got a lot of energy today? Who's feeling low energy? Today we are going to talk about energy. Energy is part of everything we do. What have you done today that used energy?

Share activities that took energy, such as getting out of bed, brushing teeth, walking, turning on light, heating water, driving car.

And where did the energy to do those things come from?

Share a variety of fuel sources, such as the food we eat, the gasoline in our cars, etc.

Let's find out. Energy is stored in many different forms. Energy cannot be created or destroyed. It is transferred or transformed from one form to another. We are going to play a game that explores how energy is transferred in order to provide energy for those things we do in our everyday lives (mention some of the activities that came up). In this game, you will each represent something that uses, transfers, and/or stores energy.

To do:
Hand the "Human" card to one of the participants. If possible, note that person's name.

To say:
For example, [NAME] will be a human being – that should be easy. Your task is to read the back of your card to find out where you get your energy, and then put your hand on the back of the person who represents that source of energy. Your energy source is written in bold letters on the back of your card. [NAME], please read the back of your card aloud and tell us: where does your energy come from?

Reads back of card: "I get my energy from the food I eat. My food can be both plant- and animal-based."

So, you would be looking for someone with a card that has something you can eat to give you energy. You would then put your hand on that person's back. Then you might have to walk around with that person to find his or her source of energy. You might also end up linking with more than one person.

To do:
Pass out a card to each participant.

To say:
Everyone have your cards? Any questions? Okay, let's see how quickly we can have everyone link up to their energy sources. Be sure to hold your cards up high so everyone can see them. Ready, set, go!

Look around for energy sources and form chains by placing hands on the back of the person representing the energy source.

To do:
As participants look for their energy sources, make sure that they are holding their cards high enough for everyone to see them, and assist any participants who seem lost. You may also want to help make sure that there is a somewhat even distribution. For example, if all of the electric devices (refrigerator, light bulb, computer) are linking to a particular power plant (solar, wind, thermal), you might want to suggest that some of them go to a different energy source for variety.

To say:
Good, that was fast. Stay standing in place, but go ahead and drop your arms. Now let's see what we have. I am first going to rearrange you slightly.

To do:
The chains will likely be arranged in a half circle fan shape. Rearrange the chains into a complete circle around the Sun, as in the picture here.

To say:
Look around at what we have here. What do you notice?

We formed chains. The Sun is the center.

Right, the Sun is in the center, and each of these energy chains traces back to the Sun.

Let's take a closer look. I am going to ask each of you to read the back of your card and then place it on the floor/ground at your feet. There is an arrow on each of your cards. When you place your card on the ground, make sure that arrow is pointing to your energy source, that is in the direction of the person whose back your hand was on. Then step out to the edge of our circle.

To do:
Ask each person to read his/her card and follow the instructions you just gave. Start with the Sun in the center, and then work your way out along each chain.

Read cards, place them on the ground, step to edge of circle.

To say:
Now we can see all of our energy chains. What do you notice?

Share observations.


The energy chains might look something like this picture

Possible discussion points:

- You noticed that all of the energy chains trace back to the Sun in the center. What does this mean? (Wait for some answers.) The vast majority of the energy we use for all of those things we do in our everyday lives comes from the Sun.
- These chains have different lengths. Let's look at the first step in each chain, so the first card next to the Sun in each chain. What do you notice about those first steps? (Wait for some answers.) The first step from the Sun for most of the chains is green plants (the other is a solar power plant). Plants convert energy directly from the Sun to energy stored in their cells. Plants are necessary for the rest of life to access the Sun's energy.
- Did you notice that some chains are shorter than others? This is a simplified model, but these shorter chains tend to be more efficient uses of energy. Solar power converts energy from the Sun to useable energy without any extra steps in between, and a vegetarian diet provides energy converted directly from the Sun by plants without the extra steps of other animals in between.
- What else do we know about these energy sources and their impact on the environment? Some sources of energy are renewable (solar, wind), meaning that we won't ever use them all up. Others are non-renewable (petroleum, coal), meaning that we have limited supplies and once they are depleted, we can no longer use them as sources of energy. Some sources of energy have negative impacts (pollution).
- Are there sources of energy that do not trace back to the Sun? Nuclear plants generate power through nuclear fission. Non-rechargeable batteries generate electricity through a chemical reaction. But the vast majority of energy sources and life forms trace back to the Sun as the ultimate energy source. We could even argue that we would not have the energy to build nuclear power plants or batteries if we did not have the Sun.
    - Another example that might come up here is the tubeworm that lives at the bottom of the ocean where sunlight does not reach, but while it is a very interesting life form, even this creature is not totally independent of the Sun. It does not use sunlight as a direct source of energy, instead using a process known as chemosynthesis to convert oxygen, hydrogen sulfide, carbon dioxide, and other available molecules into organic molecules to provide nutrition. But the Sun is still necessary for the tubeworm to feed, since it relies on free oxygen in the water, which was released through the photosynthesis of organisms closer to the surface of the water.

Space Weather PowerPoint

What's this Activity About?

Objectives:

1) Illustrates some of the effects that solar storms have on our technologies.
2) Explores how magnetic fields cause these solar storms.
3) Explain how we see the effects of magnetism on the Sun.
4) Show how viewing the Sun in different wavelengths shows different phenomena.

Presenters: A minimum of one person. Two or more presenters are encouraged if using demonstrations or activities along with the presentation.

Visitors: This presentation is appropriate for families with older children, the general public, and school groups in fifth grade and up. Any number of visitors may participate.

Duration: Between 15 and 45 minutes, depending on the number of slides covered.

Materials:

What materials from the ToolKit do I need?

1) PowerPoint document SpaceWeather.ppt (includes script in the notes)
2) Be sure to have the movies downloaded onto your computer and linked within the presentation. (see link below)
3) (Optional) PowerPoint Script
4) (Optional) Activities and demonstrations to use during the presentation.
   See script for more information.

What must I supply?

1) Computer
2) (For large groups) Projector
3) (For large groups) Screen

Activity Script

The script for the PowerPoint can be found on the Manual & Resources CD in the PowerPoint folder. The slides also have presenter's notes that mirror the written script. The PowerPoint is structured in a way so that you can give a single 15-45 minute presentation. Feel free to change presentation in any way that fits your audience and the time you have. You may want to include some of the Additional Slides for more advanced audiences, or leave out some of the original slides for a quick introduction to solar magnetism.

You may want to include some of the demonstrations, such as the "Sun in a Different Light" banner or the "Where Does the Energy Come From?" cards to involve your audience during the presentation. See the script for more information. The PowerPoint can also be a great introduction to an activity.

Important note: Download the five movies that are used in the PowerPoint, and be sure that your computer can play the files before your presentation. You can find these on the Media & resources CD as well as online here:
http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=492